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CALIFORNIA ENERGY FLOW IN 1990

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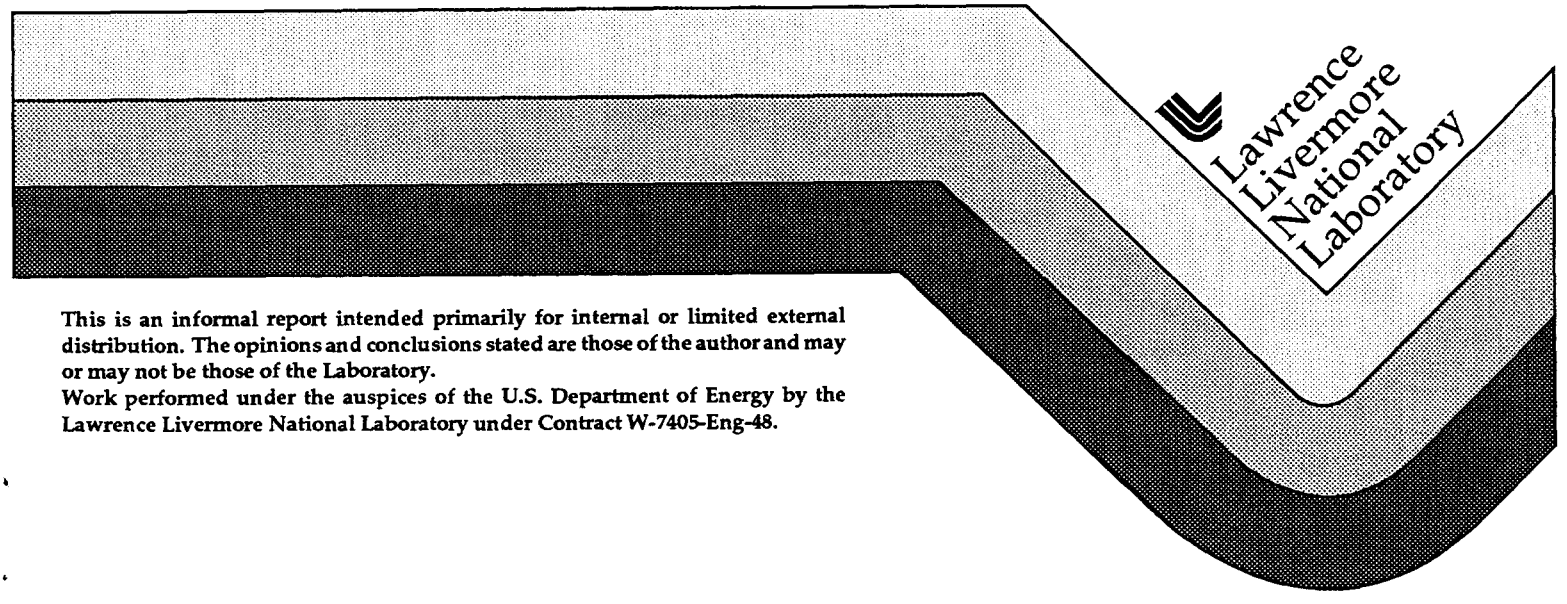

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ABSTRACT

California's total energy consumption in 1990 fell very slightly from 1989 levels, which was in keeping with tallies for the nation as a whole. The economic recession that prevailed through most of the year especially affected energy use in the industrial sector. Countering an industrial decline of 5 percent was growth in the residential/commercial and transportation end-use sectors. Both reflect a growing population as indicated by the 1990 census which estimated that the State grew 25.7 percent during the decade ending in 1990.

The State continues to rely heavily on imports of all fossil fuels and electrical power. Oil use for electrical generation continued to fall as natural gas became the preferred fossil fuel. Alternate sources of power (cogeneration, windpower, solar electricity, geothermal etc) together made a substantial contribution to distributed electricity; however geothermal, the single most important alternate source, began to decline as depletion set in at the largest geothermal field in the State (The Geysers). By contrast, power from cogenerating facilities sold to the utilities continued to increase in large part due to the growth of cogenerators within the State's heavy oil industry. For the same reason natural gas usage by that industry rose to new levels. Numerous natural gas pipelines were in some stage of construction or planning in order to provide additional fuel to fire steam boilers for enhanced oil recovery operations.

The California Air Resources Board passed a series of stringent regulations affecting automobile emissions. They mandate that by the year 2003 ten percent of new passenger vehicles have zero emissions, which is tantamount to widespread sale of electrical vehicles. The very low emission standards set for other vehicles sold at the turn of the century implies widespread introduction of automobiles fueled by alcohol or compressed natural gas.

INTRODUCTION

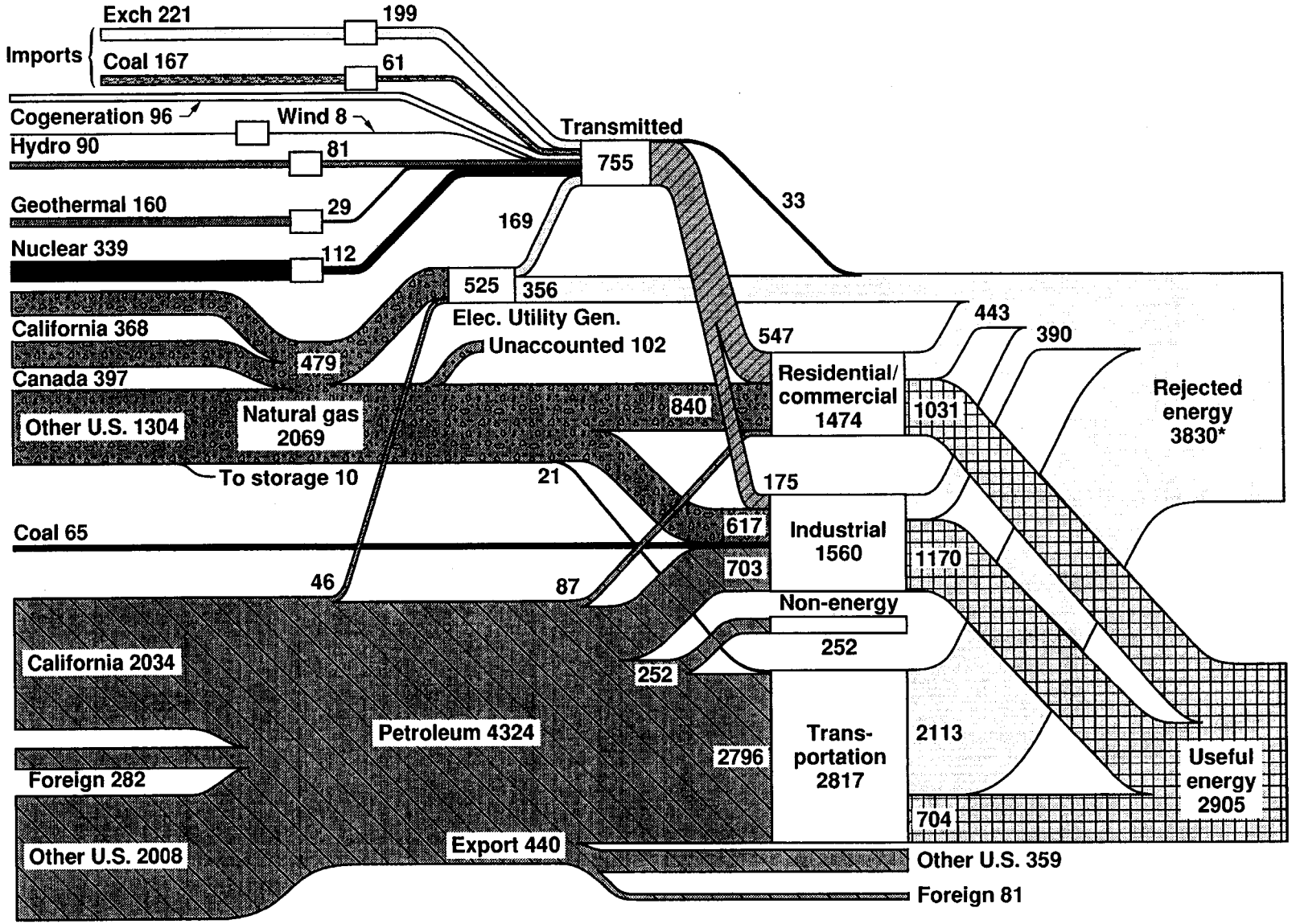
For the past fifteen years energy flow diagrams for the State of California have been prepared from available data by members of the Lawrence Livermore National Laboratory.[1] They have proven to be useful tools in graphically expressing energy supply and use in the State as well as illustrating the difference between particular years and between the State and the U.S. as a whole.

As far as is possible, similar data sources have been used to prepare the diagrams from year to year and identical assumptions[1a-1c] concerning conversion efficiencies have been made in order to minimize inconsistencies in the data and analyses. Sources of data used in this report are given in Appendix B and C; unavoidably the sources used over the 1976-1990 period have varied as some data bases are no longer available. In addition, we continue to see differences in specific data reported by different agencies for a given year. In particular, reported data on supply and usage in industrial/commercial/residential end-use categories have shown variability amongst the data gathering agencies, which bars detailed comparisons from year to year. Nonetheless, taken overall, valid generalizations can be made concerning gross trends and changes.

CALIFORNIA ENERGY FLOW DIAGRAMS

Energy flow diagrams for 1990 and 1989 are shown in Figures 1 and 2 respectively. Energy sources are shown on the left and energy consumption is shown on the right. The energy balance between the two is given in Appendix A. Also shown on the right are estimates of conversion efficiencies in the end-use sector, which result in a division between useful and rejected energy. The latter consists primarily of heat losses but also includes other sorts of losses such as line losses during electrical transmission. Inputs to total transmitted electricity such as nuclear, geothermal power, etc., are associated with estimated efficiencies of the conversion process to electricity. They vary from 90 percent in the case of hydroelectric power to 18% for geothermal energy. Assumptions concerning

CALIFORNIA ENERGY FLOW -1990
TOTAL CONSUMPTION 6900 $\times 10^{12}$ Btu



* Includes rejected energy for hydro, coal, geothermal, and nuclear conversions

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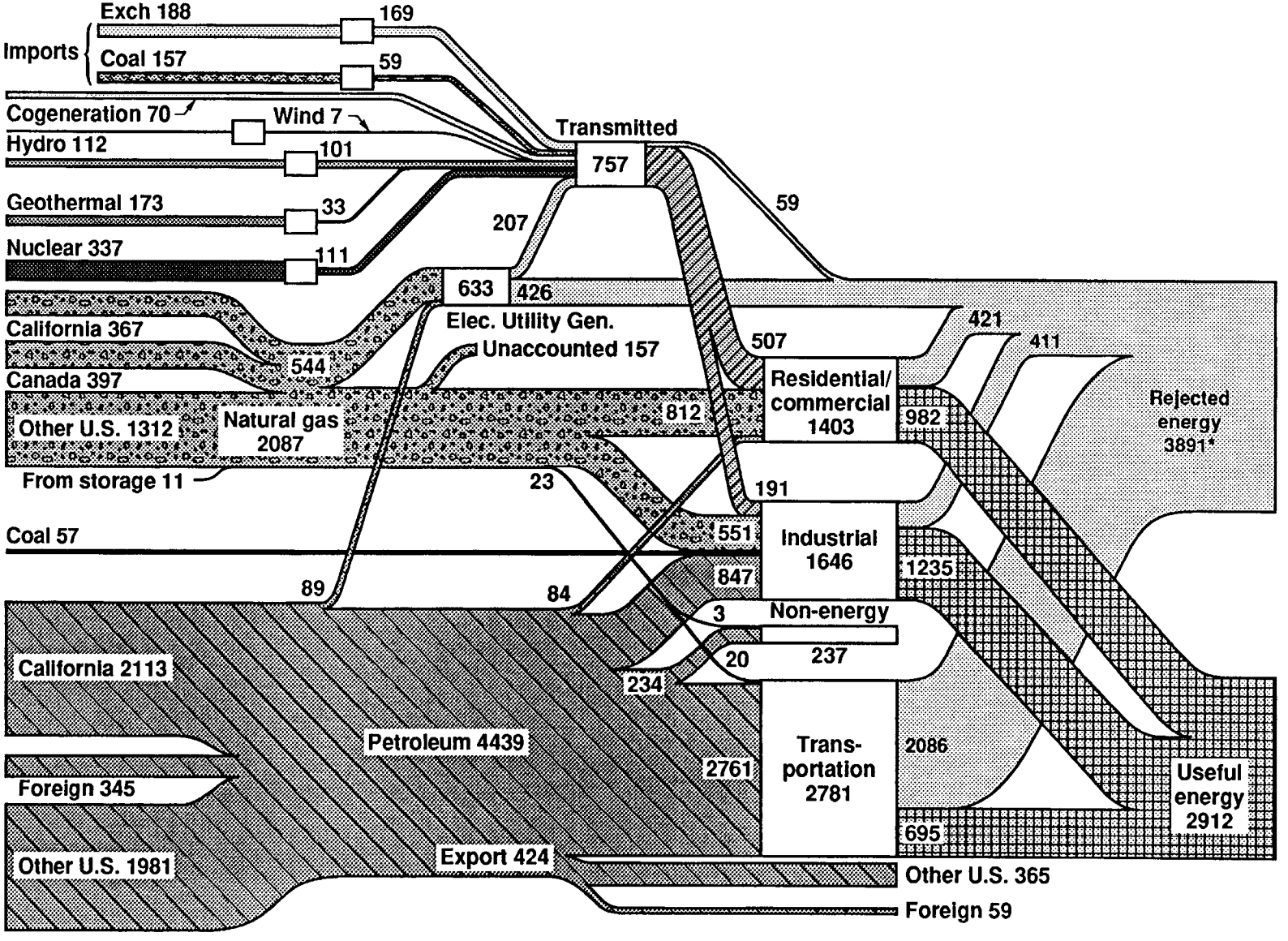
Figure 1

CALIFORNIA ENERGY FLOW -1989
TOTAL CONSUMPTION 6950 × 10^{12} Btu



* Includes rejected energy for hydro, coal, geothermal, and nuclear conversions

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Figure 2

the conversion efficiencies are given in Appendix D and their rationale can be found in Ref 1b and 1c. The box separating the energy source from the final electrical output represents the conversion process. In all cases, the quantities associated with the energy source are calculated based on assumed conversion efficiencies. While it is desirable to minimize the number of assumptions in preparing an energy flow diagram, it is also desirable to express as closely as possible the energy content of the sources used during the year. In this way changes and improvements in overall fuel conversions that occur over the course of time by virtue of fuel switching and use of renewable sources such as windpower or solar energy have an expression in the total energy consumption in the State.

Power from cogenerators and self-generators shown in the figures as inputs to total transmitted electricity appear without a box (representing the conversion process) that ordinarily would appear between the energy content of the fuel and the final product. In this instance, conversion losses are included in "rejected energy" from the industrial sector.

THE 1990 U. S. CENSUS

Preliminary census data became available in March 11, 1991.[2] California, the most populous state, comprised 29.8 million people out of a total of 248.7 million in the nation. In absolute numbers, California's population increase over the decade was almost twice that of any other state - 6.1 million (25.7 percent). The increase was in keeping with a long standing shift in population to the western sections of the country and to the "sunshine states." It also reflects immigration from Hispanic and Asian countries. Between 1980 and 1990 the Hispanic population, which can be of any race, grew by 3.1 million or 69.2 percent and was estimated to make up almost 26 percent of the State's population. The Asian segment of the State's population grew 1.6 million or 127 percent in the same interval. Subsequent to the March 1991 release the Department of Commerce announced that its surveys indicated that all minorities had been undercounted.

The increase in population and the demographic make-up of the new residents have important impacts on energy consumption particularly in the residential and transportation sectors. However in these sectors demand over the decade increased only 10 and 15 percent respectively attesting to

significant improvements in conversion efficiencies and conservation made over the same interval. Nevertheless it probably is not valid to conclude that the numerical differences between the population increase (25.7 percent) and increases in residential and transportation consumption over the decade are an accurate measure of the effects of conservation in these end-use sectors throughout the State. Although the full impact of a new resident immigrating into the State from elsewhere in the nation usually is felt the first and subsequent years, it is not true for refugees and immigrants from disadvantaged countries who made up a substantial share of the new residents. For the latter group, the ultimate impact on energy demand is unlikely to be evident the first year of arrival. Instead their consumption tends to increase annually over a number of years until their standard of living meets state and national averages. Not all of these increases are reflected in the energy consumption data of the 1980-1990 period.

Other trends evident in the census data that influence both the State's economy and energy use include an aging of the population and a second baby "boom." The median age rose from 29.9 years to 31.5 years over the decade; people 60 years or older in 1990 comprised 15 percent of the whole. Although the median age rose, the largest increase within a particular age group was recorded for children under 5 years. That group grew by 689,000 individuals, an increase of 40 percent over the 1980 total of 1,708,400 which is more than the overall population growth of 25.7%.

CALIFORNIA'S ENERGY FLOW IN 1990 COMPARED TO 1989

The economy

1990 was a recession year in the nation and in California. The recession, which gained momentum in mid-year, led to a massive State budget deficit estimated at $13 billion for the 1990-1991 and 1991-92 fiscal years combined.[3] Not only were state revenues down, but expenditures principally for health, welfare and education programs increased above budgeted amounts. The housing industry was particularly hard hit as evidenced by sluggish sales and a drop in new housing starts (Table 1).

Table 1
Construction authorized by permit - 1990[4]
Value in Millions of Dollars

Year	Residential	Nonresidential	
		Commercial	Other*
1988	26,361	6,567	7,592
1989	27,790	6,159	7,507
1990	20,686	5,279	7,466

* Other consists of all other categories including additions and alterations of $100,000 or more.

The slowdown in the construction industry was reflected in the furniture, lumber and wood products, stone/clay/glass industries, which all experienced similar declines in sales and employment. On the positive side personal income, corporate profits, and taxable sales rose 7.4, 5, and 4 percent respectively in 1990.[5]

Employment in the aerospace and electronics industries in the State fell almost 4 percent reflecting the continuing drop in Department of Defense prime contracts to California. Aerospace, particularly the defense portion, is about half as important to the State's economy as it was in the mid-1960's. Overall the unemployment rate was 5.6 percent compared to 5.1 percent the previous year and thus close to the national average of 5.5 percent.[4] However by the end of 1990 unemployment rose to 7.1 percent.[5]

Energy Consumption

Overall energy use in California fell slightly from the 1989 record year (Figure 1 and Table 2). The largest decrease was registered by the industrial sector, which more than compensated for small increases in energy used for transportation and in the residential/commercial sector. The increase in the latter sector cannot be attributed to climatic variation as the weather was slightly warmer than in 1989 in the highly populated areas of the State (Table 3). The increases in both transportation and residential/commercial sectors likely reflect an increased population. Transmitted electricity remained at 1989 levels although a larger share was directed to the residential/commercial sector and less to the industrial (Figure 1).

Table 2

Comparison of Annual Energy Use in California

(in 10^{12} Btu)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Natural Gas	1910	2010	1893	1769	1865	2034	1697	2091	1932	2087	2069
Crude Oil (less exports)	3834	3650	3327	3329	3477	3580	3601	3591	3899	4015	3884
Transmitted Electricity	622	620	642	622	700	673	697	718	744	757	755
Residential/Commercial	1334	1370	1225	1268	1176	1325	1224	1325	1350	1403	1474
Industrial	1294	1400	1570	1395	1493	1648	1456	1439	1557	1646	1560
Non-energy	298	165	158	183	221	185	203	292	235	237	252
Transportation	2471	2430	2265	2313	2464	2384	2499	2564	2715	2781	2817
Total Energy Consumption†	6400	6300	6000	5900	6200	6400	6200	6600	6750	6950	6900

† Total is not sum of above figures because of rounding and inclusion of losses associated with conversion to electrical energy.

.Table 3
Weather Comparison
1958 - 1990
Annual Heating Degree Days**

	San Francisco Federal Office Building	Los Angeles Civic Center	San Diego Lindbergh Field
1958	2332	849	805
1967	2978	1040	1380
1968	2942	850	1052
1969	3066	1032	1145
1970	3006	941	1137
1971	3468	1424	1657
1972	3240	918	1166
1973	3161	1066	1137
1974	3182	1084	1123
1975	3313	1548	1416
1976	2665	1128	793
1977	2888	911	747
1978	2599	1208	736
1979	2545	1160	902
1980	2799	597	590
1981	2819	506	573
1982	3195	975	913
1983	2386	602	623
1984	2648*	704	713
1985	2486*	921	1079
1986	1842*	473	843
1987	2150*	979	1201
1988	2194*	867	1102
1989	2526*	844	1068
1990	2340*	839	1172
Normal 1961-87	2756***	1204	1284

* CA. Mission Dolores - same historical data as for Federal Office Building

Source: Local Climatological Data for San Francisco, Los Angeles and San Diego, National Oceanic and Atmospheric Admin., National Climatic Data, Asheville, N.C.

** A "degree day" is a term that describes the relationship of energy consumption to outdoor temperatures. "Heating or cooling degree days" are deviations of the mean daily temperature from 65° F. For example for a day with a mean temperature of 40°F, the "heating degree days" would be 25 and the "cooling degree days" 0. Annual heating degree days are the sum for the year. Greater number of heating degree days means greater fuel requirements.

*** Revised by W.J. Koss, NOAA, September 7, 1988.

Within the industrial sector, use of natural gas increased while petroleum consumption declined. A part of this trend is due to fuel switching in the heavy oil industry where increasing amounts of natural gas are being used to raise steam for enhanced oil recovery. Also influencing the amount of natural gas used in the industrial sector are the growing number of cogenerators and self-generators whose fuel of choice is natural gas.

TRANSPORTATION FUELS

Consumption

The transportation sector continued to grow reflecting in large part the increase in the State's population (Table 4), which apparently more than compensated for the improved average mileage of the highway fleet. Not

Table 4
California Transportation End Use
(in 10^{12} Btu)

	1984	1985	1986	1987	1988	1989	1990
Net gasoline	1413	1445	1543	1576	1612	1630	1664
Net aviation fuel	348	379	392	390	427	458	475
Taxable diesel fuel -public highways	201	207	218	174	244	265	253
Rail diesel	27	31	31	30	26	30	31
Net bunkering fuel	390	274	267	347	357	348	344
Military	40	33	35	28	29	30	29
Natural gas-pipeline fuel	11	12	15	13	20	20	21
Total*	2431	2384	2499	2565	2715	2781	2817

n.a.: not available
* Some electricity is used for mass transit; however the amount is not monitored on a state-wide basis and hence does not appear in this table or in Figures 1 and 2.
Source: Fuel and Kerosene Sales, DOE/EIA, 1990: Quarterly Oil Report, Fourth Quarter 90 (Net gasoline and aviation fuel), California Energy Commission, Sacramento, CA.

only did estimated vehicle miles of travel on the State highway system increase 3.60 percent, but also ridership on all intercity and commuter rail systems increased to record levels.[6] Only the commercial users (taxable diesel fuel, bunkering fuels, etc.) showed a decline in 1990, which may reflect the economic recession felt throughout the year. The number of new commercial registrations also declined.[6]

Automobile emission standards

In September The California Air Resources Board (CARB) adopted a new set of emissions standards effective in 1993 that are not only stringent but contain provisions that mandate a gradual change in the type of vehicles sold in the State. The regulations require that by the years 1998 and 2003 two and ten percent respectively of all cars sold have zero emissions. By 2003 most of the remainder sold are to meet standards seventy percent below the 1993 level.[7] The measures calling for vehicles with zero emissions imply the sale of as many as 200,000 electric vehicles in 2003 based on an estimated increase in the number of new automobiles that would be sold annually — from 1.46 million in 1990 to about 2 million.[6] The very low emission standard set at the turn of the century for all other vehicles sold implies the widespread use of methanol or compressed natural gas.

The bold move on the part of the California Air Resources Board was bolstered by past successes in abating hydrocarbon pollution in the State through regulation. California sets its standards independently of the U.S. Environmental Protection Agency, and historically they have proven to be models for other states and subsequent federal legislation. The CARB is an agency comprised of appointed officials with jurisdiction over all air-quality regulation. Its actions do not require legislative approval, and there is no appeal except in the courts, an avenue that has not been pursued to date.

Critics of the new regulations question the time table for the new standards. The technology to mass produce electric and alcohol cars does not exist today. In addition state-of-the-art electric vehicles have limited appeal because of their short range and modest power, both reflections on the technical limitations of their batteries. A decade of development almost certainly would result in improvement; however there is some doubt that sales would rise to 200,000 vehicles per year in view of the expected high costs for development, retooling and manufacture that would be passed on to the customer.

Although the automobile industry under federal incentives is pursuing the development of alcohol-fueled vehicles, wholesale use is anticipated to require additional large investments in methanol production facilities, which in the near future may be more expensive than a reformulated conventional gasoline according to oil industry spokesmen.[8]

Another consideration affecting the widespread use of methanol is the availability of natural gas, the current feedstock used in the production of methanol. Like U.S. crude oil reserves, natural gas reserves have continued to fall annually and are a little more than half of what they were in 1970.[9] Some proponents of alternate alcohol fuels advocate the use of the nation's vast coal resource as a feedstock. While a viable option, the economics associated with the use of coal are uncertain.

The California consumer may balk at high prices associated with non-polluting vehicles as evidenced by the sound defeat at the polls of the California Environmental Protection Act of 1990, called the "Big Green Initiative." It proposed to raise gasoline prices by 25-50 cents/gal by 2000 and double that by 2010, restrict buyer choice of automobiles to those with fuel efficiencies of 40 miles per gallon or greater, double the price of diesel fuel for commercial transportation, and force restrictions on auto use if high prices and efficiency regulations did not cut CO_2 emissions.[10]

OIL AND GAS PRODUCTION

Oil Production

State oil production ranked fourth in the nation after Texas, Alaska and Louisiana; however predictably it declined for the fifth year in a row.[11] Decline was registered in all onshore and offshore fields except Midway-Sunset, Coalinga, Kern Front and Lost Hills. The latter fields registered increases due to enhanced oil recovery operations. Steam flooding constituted 79 percent of all incremental oil production in the State.

Midway-Sunset reached its peak production since its discovery in 1894, and in so doing became the largest oil producer in the lower 48 states. Its cumulative production reached almost 2 billion barrels by year-end, a distinction shared by only three other super-giant oil fields in the U.S. (Prudhoe Bay, AK, East Texas, TX and Wilmington, CA).

Construction of cogeneration plants to simultaneously raise steam for steam flooding and electrical production continued in heavy oil fields throughout the State. The total cogenerating capacity in the State's oil fields reached 2,023 megawatts in 1990.[11] Most of the capacity (1,762 megawatts) was operating in Oil and Gas District No. 4 near Bakersfield, which contains the Midway-Sunset, Kern Front, Elk Hills, South Belridge, and Lost Hills fields. With exception of a few plants fueled by crude oil

(Kern River) and coal (Poso Creek and Jasmin), the preferred cogeneration fuel is natural gas or casinghead gas. At the end of the year construction started on the Kern River gas pipeline, one of two new pipelines designed to bring gas to cogenerating plants. The Kern River gas pipeline will supply 700 million cubic feet of gas from Wyoming, and the second, the Mojave pipeline, will supply 400 million cubic feet of gas from the southwest U.S. upon its completion in early 1992.

The offshore Point Arguello field, the largest oil discovery in the U.S. since Prudhoe Bay, AK, finished its third idle year locked in controversy over how its production would be brought to shore. Chevron, the operating company for a consortium of oil companies, had hoped to tanker the oil to its Los Angeles refinery while a new onshore pipeline was constructed; however Santa Barbara County officials oppose any tanker traffic offshore because of potential oil spills. They contend that existing pipelines are adequate to move the estimated 75,000 barrel per day production to either Texas or to Central California from where by an indirect route it could be directed to Chevron's Los Angeles refinery.[12] Chevron and its partners have declined to pursue this alternative because of the high cost associated with the long transport and the fact that the heavy, low priced Point Arguello crude oil must be blended with scarce, lighter hydrocarbons in order to be moved in conventional pipelines. A compromise worked out by the Department of Energy during the Kuwaiti oil crisis called for pipeline shipment of 20,000 barrels per day to local refineries where it would be used as a refinery boiler fuel and shipment of the remainder of production by tanker to Los Angeles for a maximum of four years during construction of a new, heated, direct pipeline along the Sante Fe/Southern Pacific railroads' right-of-way.[13] The proposal was rejected by the Santa Barbara Board of Supervisors; however Chevron announced that it would start production at the field and pipe 20,000 barrels per day while appealing the decision to the California Coastal Commission. In early 1991 the Commission rejected Chevron's appeal although the decision did not affect the movement of the 20,000 barrels to nearby refineries.[14]

Opposition of environmentalists to the tankering proposal can be traced to the disastrous Santa Barbara offshore oil "blow-out" in 1969. It was rekindled by the Valdez, Alaska tanker oil spill and more recently in February 1990 by the small (7,000 barrels) spill from British Petroleum tanker 2 miles from Chevron's El Segundo refinery in Southern California.[11]

Natural gas production

Although non-associated gas production remained at 1989 levels, gas simultaneously produced with oil decreased for the fifth year.[11] Production at the Elk Hills oil field, the State's largest natural gas producer, fell for the tenth year thereby accounting for the largest portion of the decrease. Because currently associated gas comprises slightly more than half of total California production, total California gas production in 1990 declined as well. The 1990 total is approximately half the record production of 715 billion cubic feet in 1968.

NATURAL GAS SUPPLY

About 82 percent of the natural gas used in the State is imported, principally from the southwestern sectors of the U.S. (Figure 1). The portion that arrives from Canada is purchased by Pacific Gas and Electric Co. (PG&E) and transported by its subsidiary, Pacific Gas Transmission Co. (PGT). The Canadian arrangement drew criticism in 1990 for its cartel-like features. They essentially prohibit large California customers such as Spreckels Sugar Co. from buying Canadian gas directly from Canadian producers at lower spot market prices than contractual prices paid by PG&E since the industrial buyers have no way to transport it to California.[15] In response to the criticism the California Public Utility Commission in September 1990 required PGT to carry other customer's gas; however it effectively endorsed a Canadian condition that U.S. buyers look only to members of the gas pool supplying gas to PG&E for their gas. The subject is not considered to be closed as long as a substantial difference exists between the average price of natural gas from all Canadian producers and the price PG&E pays its Alberta suppliers.

In 1988 there were eight pipeline proposals to bring additional gas into the State before the Federal Energy Regulatory Commission (FERC). Some proposals were subsequently withdrawn, one merged with another (Mojave Pipeline Co. with Kern River Gas Transmission Co.) two were issued a final certificate by FERC (Kern River Gas Transmission and Wyoming California Pipeline Co.) in 1989 and at the end of 1990 two awaited approval. During 1990 Coastal Corp abandoned plans to build the Wyoming-California line claiming that the market was not big enough to support both its proposed

line and the larger Kern River project.[16] The bulk of the new gas is destined for enhanced oil recovery (EOR) projects in the southern part of the State.

Of the two proposals awaiting approval, only expansion of Pacific Gas Transmission Co.'s existing line proposes to serve utilities and non-EOR customers. It is designed to carry 755 million cubic feet per day to California and 148 million CF/day to the Pacific Northwest[17] and will about double the existing pipeline's capacity. The second pipeline proposal affecting California natural gas supply is from Altamont Gas Transmission Co. which will bring 719 million CF/day from the Montana-Alberta border to southwestern Wyoming where it will connect with the Kern River Gas Transmission line to southern California.[18]

ELECTRICAL POWER

Source of Supply

The largest single source of electricity in the State is imports principally from the Pacific northwest (Table 5). Included in the imports are 13 trillion Btu from the Palo Verde nuclear reactors in Arizona representing California utilities' ca. 20 percent interest in those facilities. The remaining two-thirds derive from California fossil fuel plants, nuclear plants, water power and a growing cogeneration industry, which sells excess power to the utilities. Power from oil-fired generation plants decreased again in 1990 and made a small contribution to total generation. California utility electric capacity is 43.69 GWe (Table 6) and is augmented by about 7-8 GWe from municipal and private generators, who supply power intermittently to the grid, e.g. wind generators, solar facilities, and cogenerators. Their nominal capacity is not base load capacity.

Table 5
Sources of California Utilities' Electricity - 1990

Source		Net electrical energy (trillion Btu)
Imports		260
Out-of-state coal facilities	61	
Purchases	199	
Fossil fuels		169
Natural gas	154	
Oil	15	
Nuclear power		112
Hydropower		81
Geothermal power		29
Windpower		8
Cogeneration		96
TOTAL		755

Table 6
California Utility Electrical Generating Capacity[19]

Primary energy Capacity source	(GWe)
Petroleum	3.20
Gas	21.00
Water	12.73
Nuclear	4.75
Other (principally geothermal)	2.01
TOTAL	43.69

* Summer capability as of December 31, 1990

The biennial resource plan developed by the California Public Utility Commission (CPUC) established that within the 1990-1997 time frame two of the three major investor-owned electric utilities in the State would not require new generation facilities.[20] Only San Diego Gas and Electric Co. (SDG&E) requires several hundred megawatts of new capacity, which in the CPUC view could be supplied by qualified facilities, i.e. cogenerators or small power producers who under the Public Utility Regulatory Policies Act of 1978 sell power to the utilities. The CPUC took no further action pending

the outcome of the proposed merger of SDG&E and Southern California Edison Co.

The merger proposed in 1988 would create the largest public utility in the nation, a distinction currently held by another California utility, Pacific Gas and Electric Co. Approvals are required from the Federal Energy Regulatory Commission (FERC) and the CPUC, and by year end, a FERC administrative law judge ruled against the merger on competitive grounds.[21] While the CPUC has the option to overrule the decision, such action is unlikely in view of an earlier unfavorable analysis by the CPUC's Division of Ratepayers Advocates.

With the closure of the Rancho Seco nuclear plant (873 MWe-net) by voter referendum in 1989, the unregulated, operating utility, Sacramento Municipal Utility District (SMUD), began an intensive search for alternative sources of power. Because of a series of malfunctions at Rancho Seco, the aging plant had not operated at capacity in the years prior to formal closure. As a consequence, the large publicly owned utility had been purchasing power to meet demand as an interim solution. SMUD ultimately rejected as too expensive a proposal by a private company to restructure the plant as a large natural gas-fired generating unit such as had been done with the retired Midland nuclear plant in Michigan.[22] SMUD directors plan to make up the short fall by the 1995-2000 period. The proposed expansion includes construction of at least four small natural gas-powered cogeneration plants for a total of 465 MW, a 50 MW wind farm in Solano County, solar and geothermal units and a pump-storage unit at SMUD's existing small American River hydroelectric plant. Together with the growing number of cogenerators using natural gas, these new facilities will increase the State's need for additional, out-of-state gas supplies.

Renewable sources of electricity

Geothermal

Of the 2.719 GWe of net geothermal capacity in the U.S. at the end of 1990 2.553 GWe were installed in California.[23] The Geysers geothermal field near Calistoga, CA accounted for 1.866 GWe (Table 7) and the bulk of the power production.

For the third year steam production at The Geysers declined, and for the first time in 13 years no new power plants were either completed or under construction. In 1960 steam pressure across the entire steam reservoir

was 500 pounds per square inch (psi), and by 1990 many of the 439 producing wells had steam pressures of 200 psi or less. Since historically The Geysers have provided 4-5 percent of net electrical energy in the State, the production decline has caused considerable concern to public agencies and utilities dependent on the power. In an effort to determine how to counteract the trend, the California Energy Commission set up a technical advisory committee to assess the situation. Recommendations by the committee were to (1) artificially recharge the reservoir by injecting

Table 7
Geothermal installations in California (1990)[11]

Field	Net capacity (megawatts)	Steam/fluid production (billions of kilograms)
Coso Hot Springs	252	55.9
East Mesa	102	79.2
The Geysers	1,866	95.6
Heber	47	29.5
Mono-Long Valley	34	7.0
Salton Sea	219	75.5
Wendell-Amedee	33	8.0
Total	2,553	350.7

surface water or (2) permanently curtail steam production.[24] To implement the second recommendation, operators at the field, principally Unocal Corporation and the Northern California Power Agency, inaugurated a "load following" method of operation with some success, i.e. an operation whereby more steam from wells is produced during peak hours of electrical demand than during hours of minimal demand. Reinjection of condensed steam, a practice of many years standing, constituted 29 percent of fluid production in 1990, up several percent from the amount injected a decade earlier. However because of the drought of some years' standing in the State, implementation of the first recommendation is not considered to be viable at present. As a consequence, Pacific Gas and Electric Co., the utility purchasing most of the electricity produced, predicts continued decline in both steam and power production.

A brighter picture emerges at some of the water-dominated geothermal areas - specifically at Coso, East Mesa and Salton Sea where fluids produced as well as generating capacity have increased annually for several years. Capital costs associated with generating plants (50 MWe) required for liquid-dominated geothermal areas are estimated to be $3100 per installed kilowatt for a binary system and about $2400 per installed kilowatt for flash systems;[25] and thus several times the costs associated with development of a vapor-dominated resource such as The Geysers. Nonetheless expansion at all three water-dominated fields is expected to continue despite large capital costs and declining "avoided costs," the amount utilities are required to pay geothermal developers for power produced. In 1990 "avoided costs" to geothermal producers were less than 2 cents/kWh.[26]

Solar electricity

Expansion at the Luz International Ltd. solar installation was well underway at Kramer Junction in the Mojave Desert. The world's largest solar electrical plant (150 MW) consists of 600 acres of parabolic collectors that track the sun across the sky. Together with other Luz solar installations in the Mojave Desert, output constitutes 90 percent of all the solar electrical power generated in the world. Notwithstanding world ranking, the plants are still in the experimental stage of development and do not contribute substantially to California's electrical supply. Significant progress has been made in the last decade in bringing costs down. According to Luz spokesmen, the cost of electrical generation has fallen dramatically from 25 cents per kWh for the first plant constructed in 1983 to the current cost of about 8 cents per kWh, and refinement is hoped to bring the cost down to 5 cents per kWh in 5 years.

Additional capacity (80 MW) dedicated to San Diego Gas and Electric Co. is scheduled for completion in 1994. Beyond that Luz is looking for firm utility markets in California and Nevada to buy the solar power in order to qualify construction of additional units for favorable tax status under the Public Utility Regulatory Policies Act (PURPA).[27] The most important elements of the Act are tax exempt financing and 20 percent combined federal and state tax credits. Luz expects to take advantage of the recent change in the ceiling on the size of facilities qualifying for the special PURPA provisions initially set at 80 MW and concentrate on 200 MW units,

which is closer to the optimum power block for their type of installations. They also are hoping that Congress will lift the PURPA requirement that only 25 percent of the output of the units be generated with fossil fuels. Elimination of that requirement would allow them to more nearly approximate a base load plant that operates 24 hours per day.

Three California utilities (Southern California Edison, Sacramento Municipal Utility District and Los Angeles Department of Water and Power) also announced plans to construct a 10 MW advanced solar plant in the Mojave Desert.[28] The plant will consist of hundreds of large tracking mirrors on a 300-foot tower. Molten nitrate salts will provide heat storage at a higher temperature than possible with oil, the conventional storage media and thus provide an additional four hours of power generation. With adequate financing, start-up is scheduled for 1994.

Windpower

Over 90 percent of windpower capacity in the United States is located in California; most of the remainder is located in Hawaii. All totaled installed capacity in California reached 1454 MWe (Table 8), which represents the largest concentration in the world. An estimated 100 MWe of wind capacity exists elsewhere in the world.[29]

In 1990 increases were registered in the amount of electricity generated (from 2.079 billion kWh to 2.423 billion kWh) as well as in installed capacity (Table 8). The largest single additions were in Solano County, where U.S. Windpower started up 600 new windmills in the State's newest wind farm;[30] however increases were registered in almost all principal operating areas. An important factor in the increased output was the increase in the average capacity factor from 18 percent to 20 percent.[31] The average, statewide capacity factor is the ratio of the actual output to the amount of energy that could be produced if operated at full rated power, 24 hours per day over a given period. The theoretical maximum capacity factor varies from region to region depending on the seasonal wind patterns. The technically achievable state average is probably between 25 and 30%.

The growth of the industry was negatively impacted by the expiration of generous state and federal tax credits in 1985 and 1986. Subsequently financing of the wind development has depended more on conventional institutional financing than on the venture capital that had been attracted

to the industry initially. The industry's profitability in the ensuing years hinged on the prices paid by the utilities for the power. Under early so-

Table 8
Windpower Installations in California as of January 1

Location	Capacity (MW_e)				Number of turbines			
	1988	1989	1990	1991	1988	1989	1990	1991
Altamont Pass area 45 miles east of San Francisco	654	623	659	687	6615	6062	6242	6524
San Gorgonio Pass Riverside Co. near Palm Springs	254	206	224	229	3830	3322	3388	3333
Tehachapi Pass, Kern Co.	393	370	417	477	4480	4007	4414	4422
Mojave Desert Kern Co.	0				0			
Boulevard, San Diego Co.	0.8				36			
Carquinez Strait, Solano Co.	0.63	2	2	61	6	66	62	631
Pacheco Pass, San Benito Co.	0.5				20			
Salinas Valley	0.16				4			
TOTAL	1304	1202	1302	1454	14991	13457	14106	14910
Capacity Factor	16	17	18	20				

Source: Results from the Wind Project Performance System, Annual Reports, 1987,1988, 1989, 1990, California Energy Commission, Sacramento, CA.

called Standard Offer #4 contracts with the utilities that ran from 15 to 30 years producers were guaranteed fixed energy prices for one-third of the contract term up to ten years.[32] Because of the high "avoided costs" for new, conventional generating capacity that prevailed in the early eighties, contracts concluded at that time called for purchases at seven to nine cents per kWh.[29] By mid-1990 most sales under long term contracts no longer enjoyed these favorable rates. Also with the end of the energy supply shortage and the realization that installed electrical capacity in the State was adequate, if not in surplus, for the foreseeable future, new Standard Offer #4 contracts were suspended. Hence most new as well as old wind

installations earn approximately three cents per kWh derived from the 1990 "avoided cost."[33]

The ultimate effect of the lower return on investment will not be apparent for several years in California. Other critical factors in addition to prices received for power are ability of the operators to further reduce the cost of operating the wind turbines, as well as to improve efficiency and capacity factors. The goal is to bring costs per kWh down to 4-5 cents and to that end a $5 million cost-sharing program between the wind companies and the U.S. Department of Energy was being formulated at year-end.[34]

CONSERVATION

In an effort to revitalize energy efficiency and conservation programs within the electric and gas utilities of the State the California Public Utilities Commission (CPUC) sponsored a collaborative effort between consumer and environmental groups, utilities and government agencies to develop a plan. In January of 1990 the product, *Energy Efficiency Blueprint for California*, was published;[20] and in August the CPUC approved an array of programs designed to provide incentives for conservation on the part of both consumers and the State's utilities.

Essentially consumers will receive rebates from utilities for purchase of energy efficient equipment and for costs associated with retrofitting existing homes and buildings with energy saving materials such as multi-paned windows and insulation.[35] The two year, $560 million program will not necessarily impact utility profits since the cost will ultimately be borne by all customers. In addition the CPUC supported the creation of new rate-making devices to provide incentives to the utilities; thus the utilities would be able to increase shareholder earnings by implementing successful programs and meeting specific goals. Several years earlier the

APPENDIX A

Energy balance for 1990 (Figure 1)

			(10^{12} Btu)
SUPPLY			
Electrical Imports			388
Wind			8
Hydro			90
Cogenerated electricity (fuels included in oil and gas supplies below)			
Geothermal			160
Nuclear			339
Natural gas			2069
Less: unaccounted for gas and net storage additions			-112
Coal			65
Petroleum			4324
Less exports			-440
Total			6891
DISPOSITION			
Useful energy			2905
Residential/commercial		1031	
Industrial		1170	
Transportation		704	
Non-energy uses			252
Rejected energy			3830
Residential/commercial		443	
Industrial		390	
Transportation		2113	
CA electric utility generation		723	
Fossil fuels	356		
Nuclear	227		
Hydro	9		
Geothermal	131		
CA transmission losses		33	
Out-of-state elec. generation and transmission losses		128	
Cogeneration (included in industrial)			-96
Total			6891

APPENDIX B

Data Sources for California Energy Supply (1990)

Production	Source
Crude Oil including Federal Offshore and Lease Condensate	Ref. 11.
Associated and Nonassociated Natural Gas (marketed, dry)	Ref. 36, Table 48, Summary Statistics for Natural Gas - California.
Electric Utility Fuel Data	Ref. 37, Table 19, Total Consumption of Petroleum to Produce Electricity; Ref. 36, Table 48.
Electrical Generation Oil, gas, hydro, nuclear	Ref. 37, Tables 8,11,14,15, and 16, Net Generation by Petrol., Gas, Hydroelectric, Nuclear Power and Other.
Wind	Ref. 31.
Cogeneration	Andrea Gough, California Energy Commission, personal communication, Nov 21, 1991.
Imports	
Natural Gas	
Foreign	Ref. 36, Table 9.
Domestic	Ref. 36, Table 48.
Crude Oil Foreign and Domestic	Ref. 38, Table 1-A, California Petroleum Summary.
Oil Products Foreign and Domestic	Ref. 38, Table A-1, California Petroleum Fuels Market Activity.
Coal	Ref. 39, Table 24, Coal Consumption by Census Division and State.

APPENDIX B -Continued

Electrical Power	
Net Exchange	Andrea Gough, California Energy Comm., personal communication, Nov. 21, 1991.
Coal	Ibid
Exports	
Oil Products	
Foreign and Domestic (not including bunkering fuel supplied at California ports)	Ref. 38, Table A-1.

APPENDIX C

Data Sources for California End Uses (1990)

Net Storage	
Natural Gas	Ref. 36, Table 48.
Unaccounted for Natural Gas	Ref. 36, Table 48.
Transportation	
Crude Oil	
Gasoline, Aviation and Jet fuels	Ref. 38, Table 1.
Taxable Diesel Fuel (for public highways)	Ref. 40, Table 11, Sales for Transportation Use: Distillate Fuel Oil and Residual Fuel Oil, 1990.
Vessel Bunkering (includes international bunkering)	Ibid.
Rail Diesel	Ibid.
Military Use	Ref. 40, Table 12, Sales for Military use, Off-highway and all other uses: Distillate fuel, Residual Fuel Oil, and Kerosene,1990.
Natural Gas	
Pipeline fuel	Ref. 36, Table 48.
Industrial, Government, Agriculture, etc.	
Natural Gas (includes lease and plant fuel)	Ref. 36, Table 48.
Coal	Ref. 39, Table 24.

Electricity	Ref. 37, Table 43, Sales of Electricity to Ultimate Consumers by Class of Service, Year to date.
Crude Oil	By Difference.
Non Energy Applications	
Crude Oil and LPG	
Asphalt	Ref. 41.
Petrochemical Feedstock	Ref. 42, Table 39 (estimate).
Waxes, Lubricating oils, Medicinal uses, Cleaning	Ref. 38, Table A-5, California Refinery Activity by Type and Area.
Residential and Small Commercial	
Natural Gas	Ref. 36, Table 48.
Crude Oil and Other Oils (kerosene, residual, and distillate)	Ref. 40, Table 6, Sales of Kerosene by End Use; Table 5, Sales of Residual Fuel Oil by End Use; Table 4, Sales of Distillate Fuel Oil by End Use.
LPG	Ref. 42, Table 39.
Miscellaneous "Off highway" Diesel	Ref. 40, Table 4.
Electricity	Ref. 37, Table 43.

APPENDIX D

Conversion Units

Energy Source	Conversion factor, 10^6 Btu
Electricity	3.415 per Mwh
Coal	22.6 per short ton
Natural Gas	1.05 per Mcf
Crude Oil	5.80 per barrel
Fuel Oil	
Residual	6.287 per barrel
Distillate, including diesel	5.825 per barrel
Gasoline and Aviation Fuel	5.248 per barrel
Kerosene	5.67 per barrel
Asphalt	6.636 per barrel
Road Oil	6.636 per barrel
Synthetic Rubber and Miscellaneous	
LPG Products	4.01 per barrel

Assumed Conversion Efficiencies of Primary Energy Supply

Electric Power Generation	
Hydro Power	90%
Coal	30%
Geothermal	18%
Oil and Gas	33%
Uranium	32%
Transportation Use	25%
Residential/Commercial Use	70%
Industrial Use	75%

REFERENCES

1. a. E. Behrin and R. Cooper, California Energy Outlook, Lawrence Livermore Laboratory Report, UCRL-51966, Rev. 1 (1976).

   b. I. Y. Borg, California Energy Flow in 1976, Lawrence Livermore Laboratory Report, UCRL-52451 (1978).

   c. A. L. Austin and S. D. Winter, U.S. Energy Flow Charts for 1950, 1970, 1980, 1985 and 1990. Lawrence Livermore Laboratory Report, UCRL-51487 (1973).

   d. I. Y. Borg, California Energy Flow in 1977, Lawrence Livermore National Laboratory, UCID-18221 (1979).

   e. I. Y. Borg and C. K. Briggs, California Energy Flow in 1978, 1979, 1980, 1981, 1982, 1983, 1985, 1986, 1987, 1988, 1989, Lawrence Livermore Laboratory Reports, UCID-18760 (1980), UCID-18991 (1981), 18991-80 (1982), 18991-81 (1983), 18991-82 (1983), 18991-83 (1984), 18991-85 (1986), 18991-86 (1987), 18991-87 (1989), 18991-88 (1989), 18991-89 (1991).

   f. I. Y. Borg and C. K. Briggs, "California's Energy Supply and Demand in 1984," Annual Review of Energy *11*. (1986) p. 209-28.

2. "Census Bureau completes distribution of 1990 redistricting tabulations to States," U. S. Department of Commerce News, Washington, D.C., Release CB 91-100 (March 11, 1991) 12pp.

3 California Economic Indicators, California Department of Finance, Sacramento, CA (March/April 1991) p. 7.

4. California Statistical Abstract- 1991, California Department of Finance, Sacramento (October 1991) 206pp.

5. California Economic Indicators, California Department of Finance, Sacramento, CA (January/February 1991) p. 3.

6. Travel and Related Factors in California- Annual Summary 1990, California Department of Transportation, Sacramento, CA

7. R. W. Stevenson, "California to get tougher air rules," New York Times (September 27, 1991) p. A1.

8. D. J. Jefferson, "California adopts strictest smog laws in the nation to reduce auto pollution," The Wall Street Journal (October 1, 1990) p. A3.

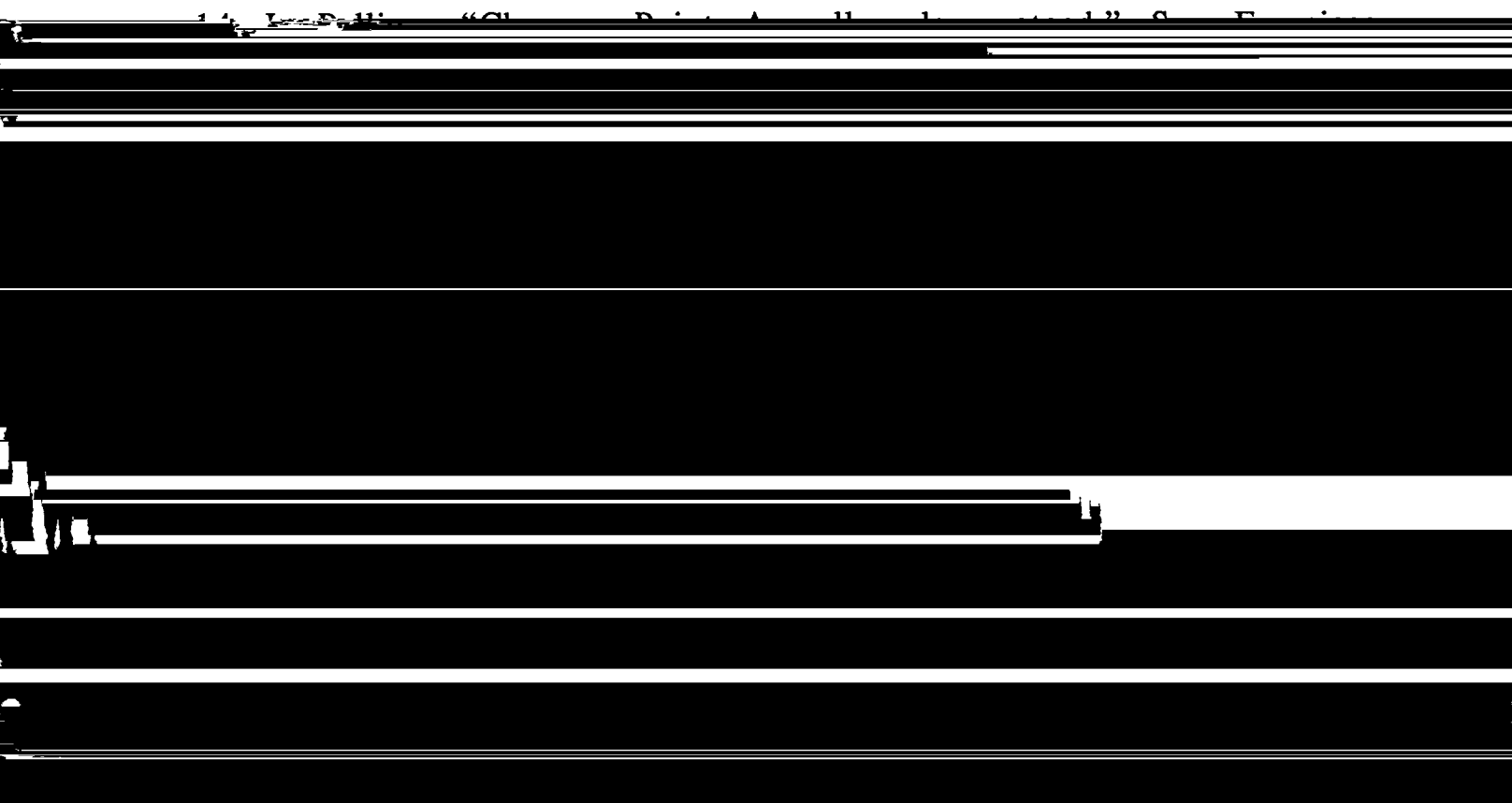
9. Twentieth Century Petroleum Statistics- 1990, DeGolyer MacNaughton, Dallas, Texas (December 1990), p. 74.

10 "Huge price tag seen for California initiative," Oil and Gas J. *88* (June 11, 1990) p. 22.

11. 76th Annual Report of the State Oil and Gas Supervisor 1990, California Department of Conservation, Division of Oil and Gas, Publ. No. PRo6, Sacramento, CA (1991).

12. B. Williams, "Point Arguello project start-up blocked again," Oil and Gas J. *88* (November 19, 1990) p. 34.

13 P. Lee, "Chevron will start pumping oil at Point Arguello," Los Angeles Times (November 28, 1990) p. D1.



19. Inventory of Power Plants in the United States 1990, U.S. Department of Energy, Washington, D.C., DOE/EIA-0095(90) (October 1991)

20. California Public Utilities Commission - Annual Report, 1989-1990, San Francisco, CA (1991)

21. J. McCaughey, "FERC law judge rejects planned merger between SCE, SDG&E," The Energy Daily *18* (November 28, 1990) p. 1.

22 "Sacramento utility's 20-year plan," San Francisco Chronicle, (July 9, 1991) p. A14.

23. Geothermal Energy in the Western Unites States and Hawaii: Resources and Projected Electricity Generation Supplies, U.S. Department of Energy, Washington, D.C., Table 2, DOE/EIA-0544 (September 1991)

24. "Geysers Watch: Part 1 - Plunging toward 'Abandonment Pressure'," Geothermal Report *19* (February 1, 1990) p. 4.

25. "Renewable Energy Technology Characterizations," Science Applications International Corporation, Inc, Alexandria, VA (September 1990) p. 3.

26. J. Egan, "As avoided costs fall, geothermal producers struggle to make money," The Energy Daily *18* (April 19, 1990) p. 3.

27 K. Maise, "How Luz is climbing Jacob's ladder to solar success in California's Mojave Desert," The Energy Daily *18* (November 7, 1990), p. 2.

28. "Advanced solar plant planned in Mojave Desert," San Francisco Chronicle (August 29, 1991) p. 2.

29. Energy Technology Status Report, P-500-90-003A, Appendix A, Volume II, California Energy Commission, Sacramento, CA (June 1991) p. II-1.

30. J. Flinn, "'Weenies' no more, Wall Street and white shirts hail wind power," The Washington Times (January 18, 1990) p. A5.

31. Results from the Wind Project Performance System - Annual Report 1990, California Energy Commission, Sacramento, CA (December 1991)

32. S. Miller, A Guidebook on Standard Offers for Electric Power Purchases, California Energy Commission, Sacramento, CA (January 1986)

33 Pacific Gas and Electric Company's Energy Prices for Qualifying Facilities, effective February 1, 1990-April 30, 1990, Application for Pacific Gas and Electric for Approval of Certain Standard Offers Pursuant to Decision 82-01-103 in Order Instituting Rulemaking No. 2, Pacific Gas and Electric Co, San Francisco, CA (January 31, 1990).

34 M. van de Kamp, "Federal funding returns to wind power industry," Tri-Valley Herald (October 30, 1991) p. B1.

35. J. Stewart, "Putting California back on energy-efficiency track:a tortuous story," Los Angeles Times (September 23, 1990) p. M5.

36. Natural Gas Annual-1990, U.S. Department of Energy, Washington, D.C, DOE/EIA-031(90) v. 1, (December 1991).

37. Electric Power Monthly, U.S. Department of Energy, Washington, D.C., DOE/EIA-0226(91/03) (March 1991)

38. Quarterly Oil Report, 4th Quarter 1990, California Energy Commission, Sacramento, CA (May 1991)

39. Quarterly Coal Report, 4th Quarter 1990, U.S. Department of Energy, Washington, DC., DOE/EIA-0121 (90) (May 1991)

40 Fuel Oil and Kerosene Sales 1990, U.S. Department of Energy, Washington, D. C., DOE/EIA-0535(90) (October 1991)

41. Asphalt Usage 1990, United States and Canada, Asphalt Institute, Lexington KY (April 1991)

42. State Energy Data Report- Consumption Estimates (1960-1989), U.S. Department of Energy, Washington, D.C., DOE/EIA-0214(89) (May 1991)

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